The IceCube Observatory
Status and Initial Results

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for the IceCube collaboration
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3 – 6 August 2010 in Turku

bmb+f - Förderschwerpunkt
Astroteilchenphysik
Großgeräte der physikalischen Grundlagenforschung

The IceCube Collaboration

USA:
Bartol Research Institute, Delaware
University of California, Berkeley
University of California, Irvine
Pennsylvania State University
Clark-Atlanta University
Ohio State University
Georgia Institute of Technology
University of Maryland
University of Alabama, Tuscaloosa
University of Wisconsin-Madison
University of Wisconsin-River Falls
Lawrence Berkeley National Lab.
University of Kansas
Southern University and A&M College, Baton Rouge
University of Alaska, Anchorage

Sweden:
Uppsala Universitet
Stockholm Universitet

UK:
Oxford University

Switzerland:
EPFL

Germany:
DESY-Zeuthen
Universität Bonn
Universität Mainz
Universität Dortmund
Universität Wuppertal
Humboldt Universität
MPI Heidelberg
RWTH Aachen
Universität Bochum

Belgium:
Université Libre de Bruxelles
Vrije Universiteit Brussel
Universiteit Gent
Université de Mons

Japan:
Chiba University

New Zealand:
University of Canterbury

34 institutions, approx. 250 members
http://icecube.wisc.edu/

Why build IceCube

- Astrophysical questions:
  - Origin of the cosmic rays
  - Uncovering "invisible" phenomena with neutrinos
  - Cosmic ray physics
- Particle physics:
  - Search for dark matter
  - Neutrinos (oscillations, …)
- Quantum gravity (and other BSM physics)
- Magnetic Monopoles

Amundsen-Scott South Pole Station

South Pole

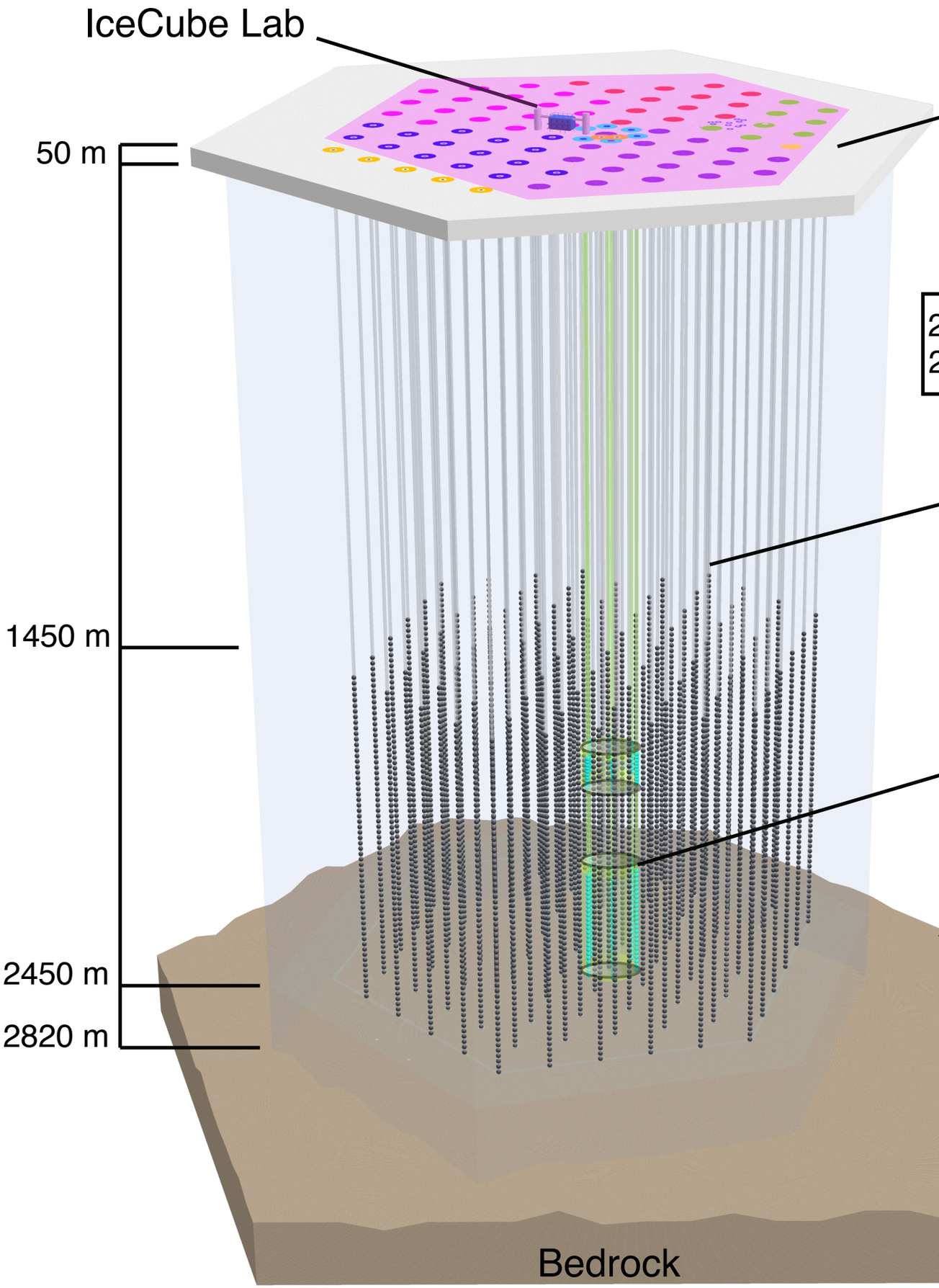
Runway

DeepCore

AMANDA
(until 2009)

IceCube

IceCube Status



IceTop
80 Stations, each with
2 IceTop Cherenkov detector tanks
2 optical sensors per tank
320 optical sensors

2010: 79 strings in operation
2011: Project completion, 86 strings

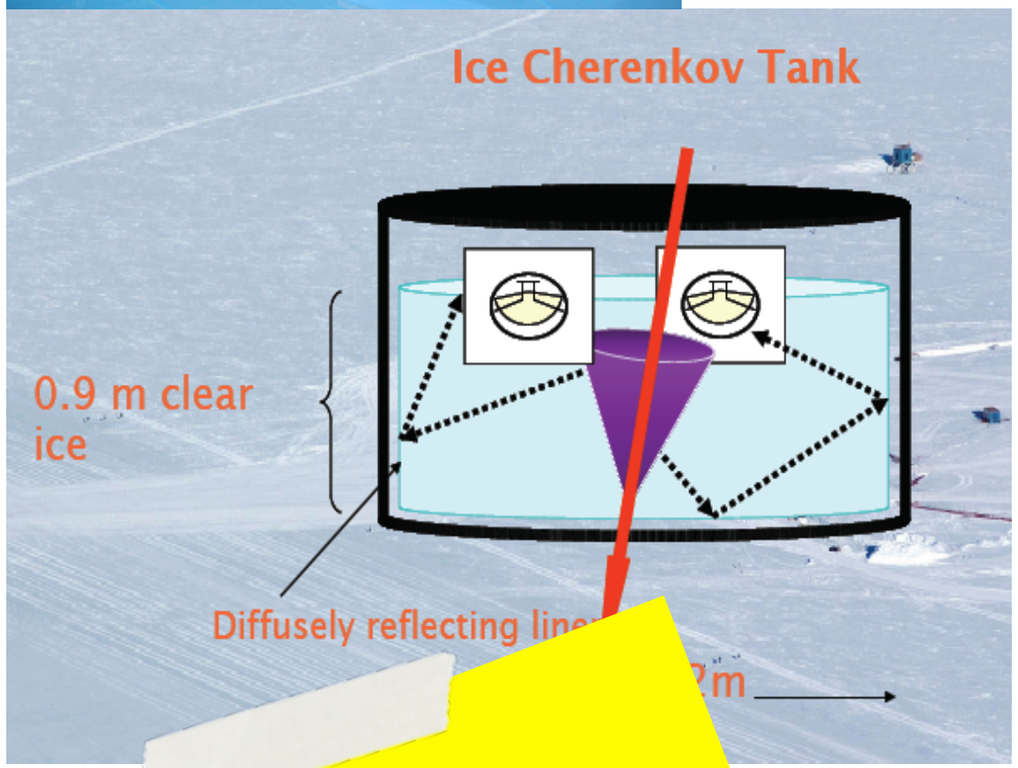
IceCube Array
86 strings including 6 DeepCore strings
60 optical sensors on each string
5160 optical sensors

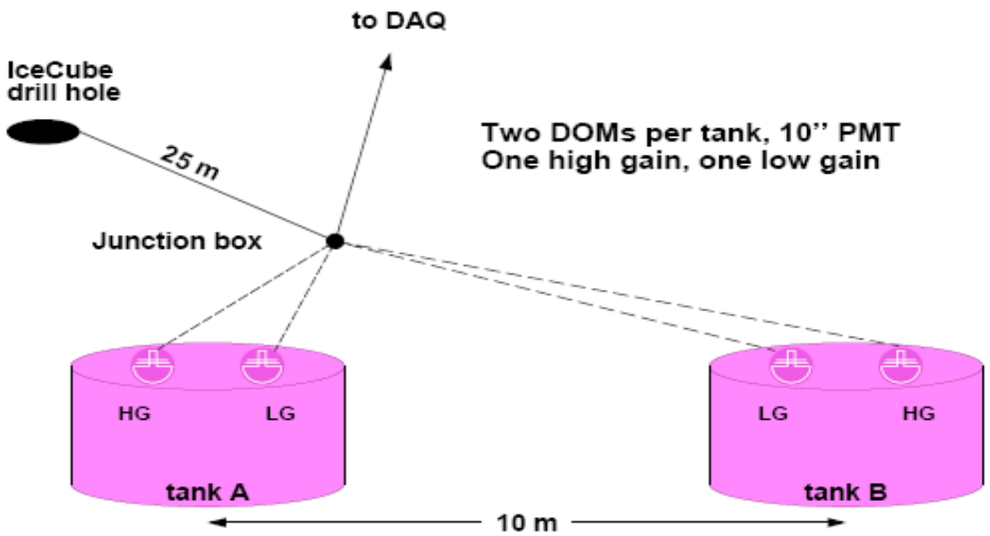
DeepCore
6 strings-spacing optimized for lower energies
360 optical sensors

Eiffel Tower
324 m

The IceTop Air Shower Array

80 stations
2 tanks each
Threshold energy:
≤ 300 TeV
Maximum energy:
limited by km^2 size

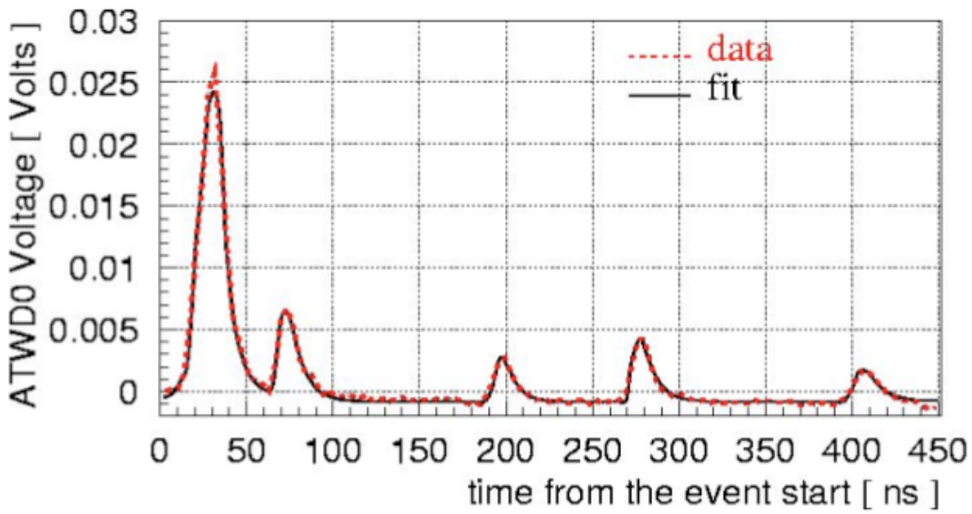




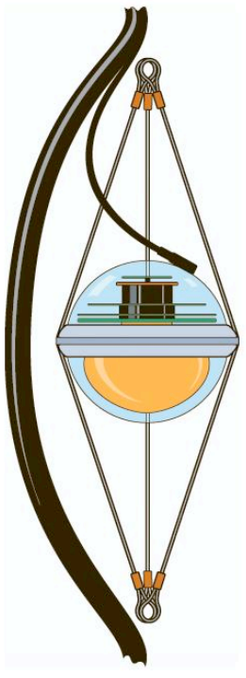
See talk by F. Kislat, poster by T. Feusels

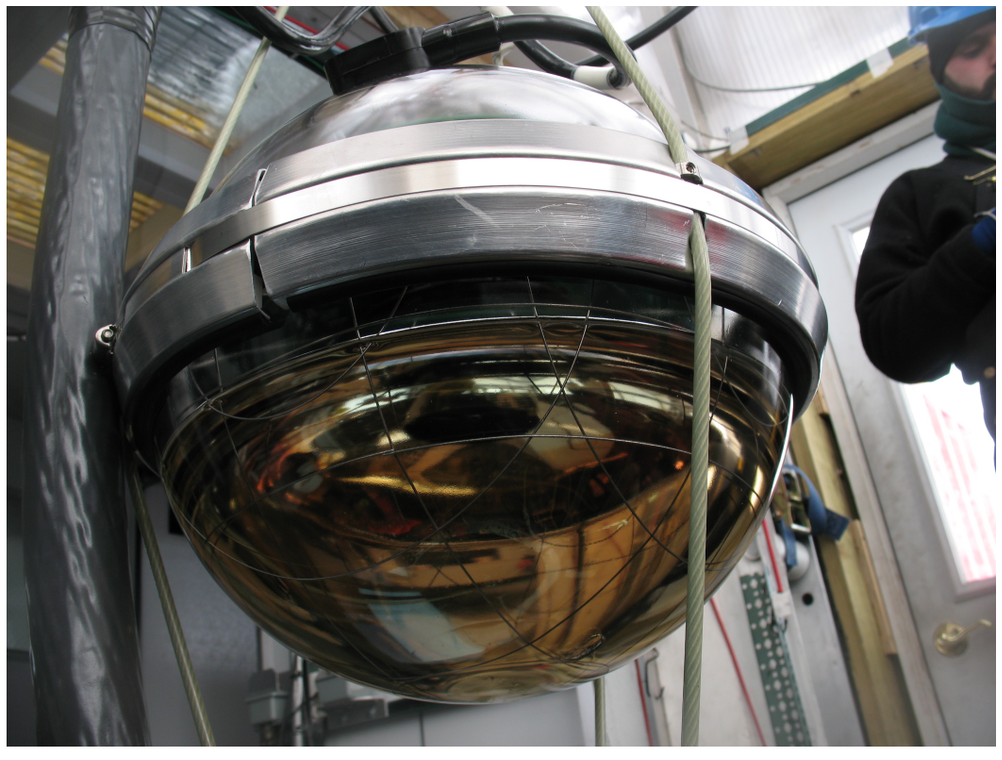
Digital Optical Module (DOM)

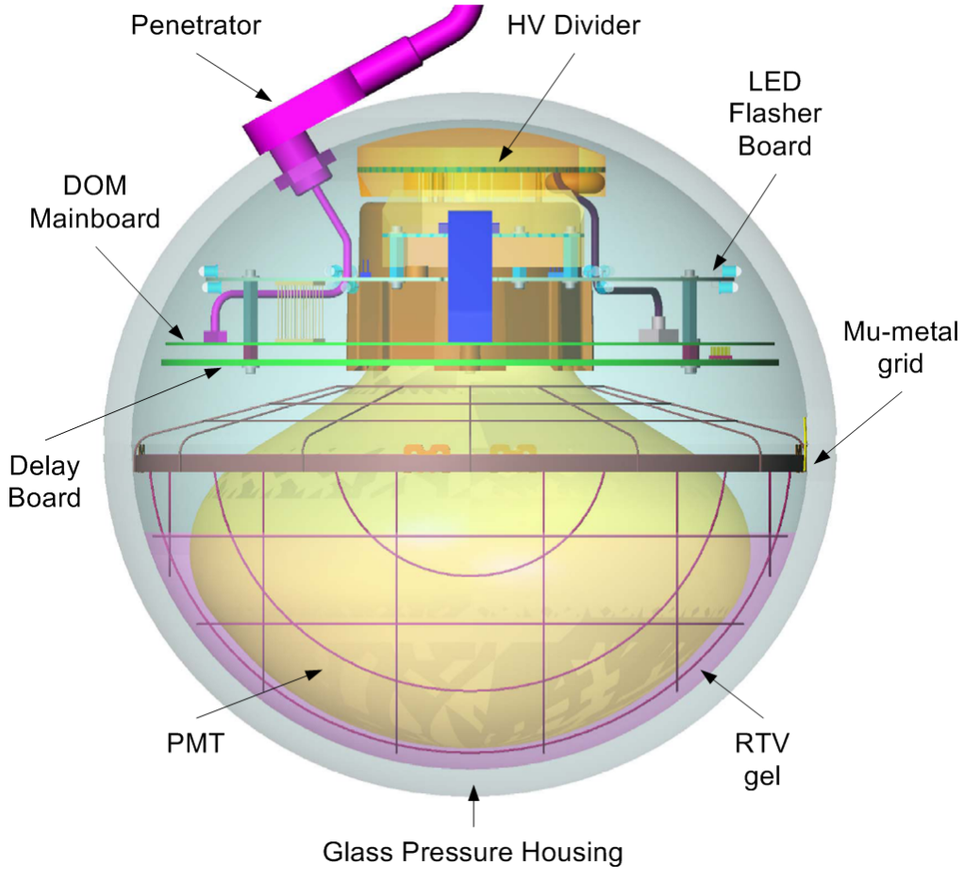
10” Hamamatsu Photomultiplier tubes (PMT)
3.5 W Power
Internal digitization and time stamping:
ATWD: 300 MHz (400 ns)
fADC: 40 MHz (6400 ns)
Dynamic range: from one to thousands of photo-electrons
Transmit digital data to surface



2 ns precision on photon arrival time



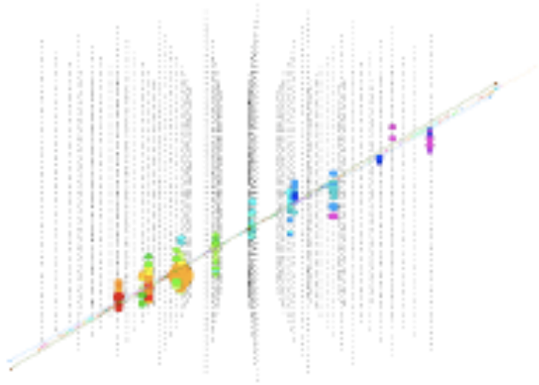




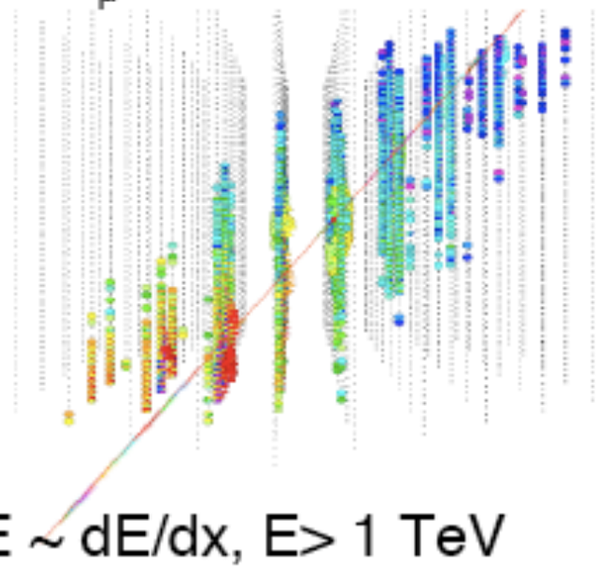
Event Topologies

Muon neutrino

a) E_μ=10 TeV ~ 90 hits



b) E_μ=6 PeV ~1000 hits

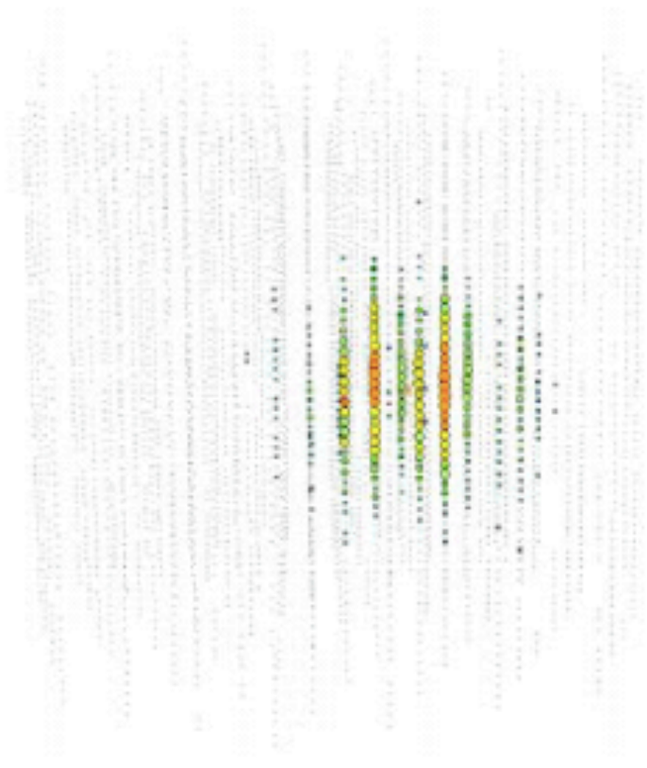


E ~ dE/dx, E> 1 TeV

Energy Res. : log(E)~0.3
Angular Res.: 0.8 -2 deg

Electron neutrino

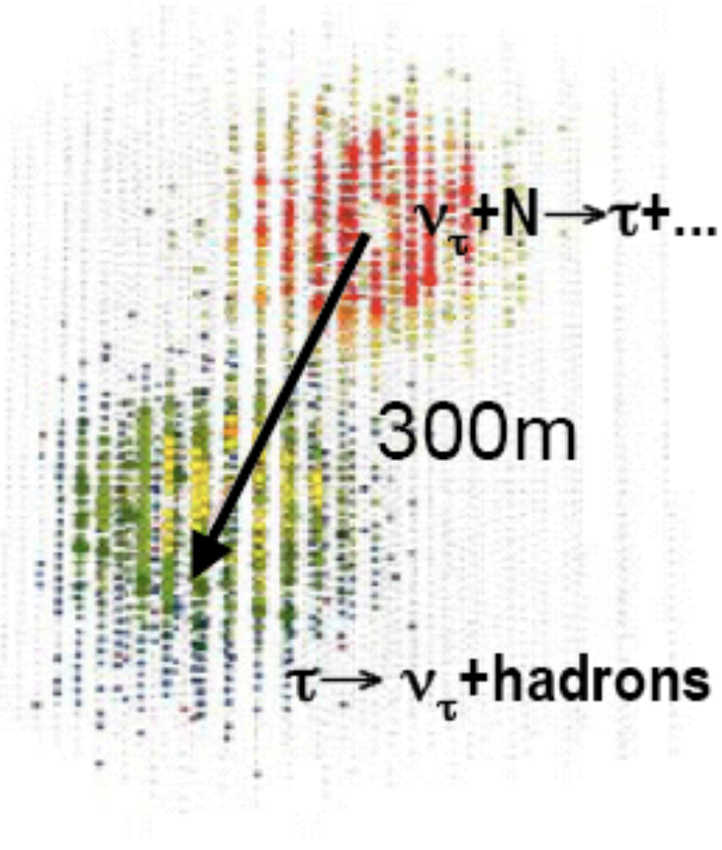
E = 375 TeV



Energy Res. log(E)~0.1-0.2
Poor Angular Resolution

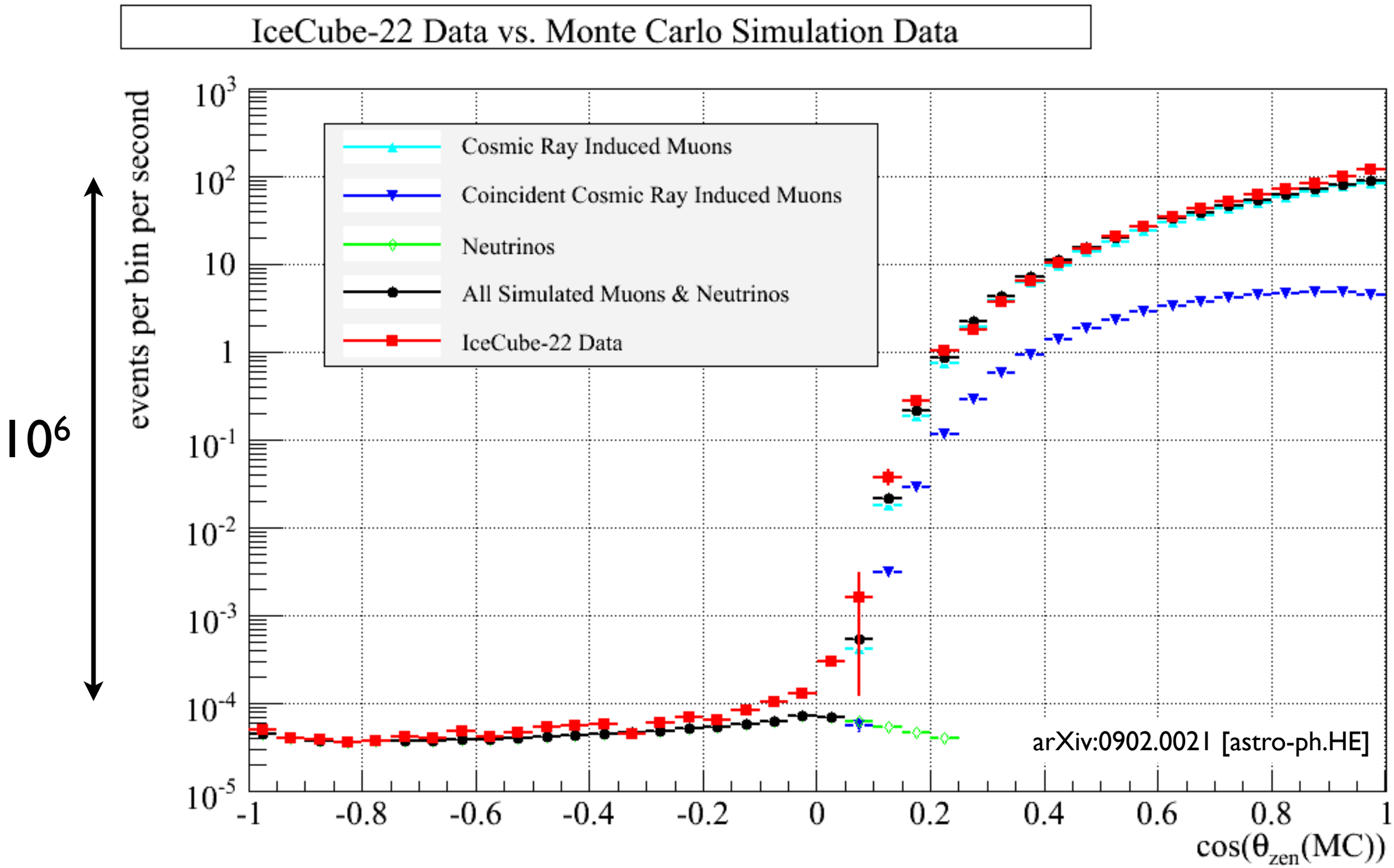
Tau neutrino

E = 10 PeV



Double-bang signature
above ~ 1 PeV
Very low background
Pointing capability
Best energy measurement

The Challenge: Rejecting Atmospheric Muons



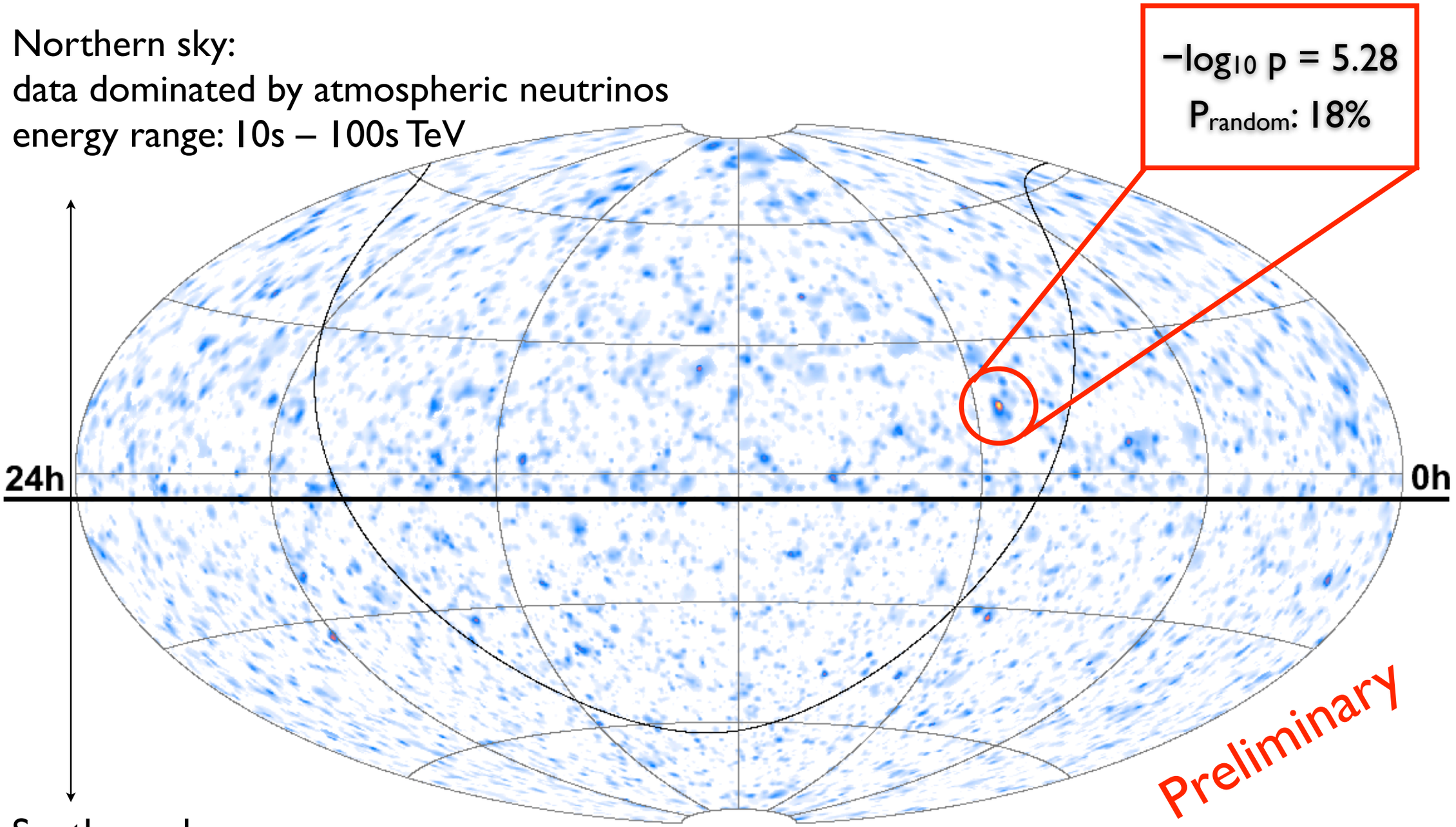
10^6

All sky muon flux measured with IceCube 22 strings

IceCube Results

IceCube 40-string Point Source Search

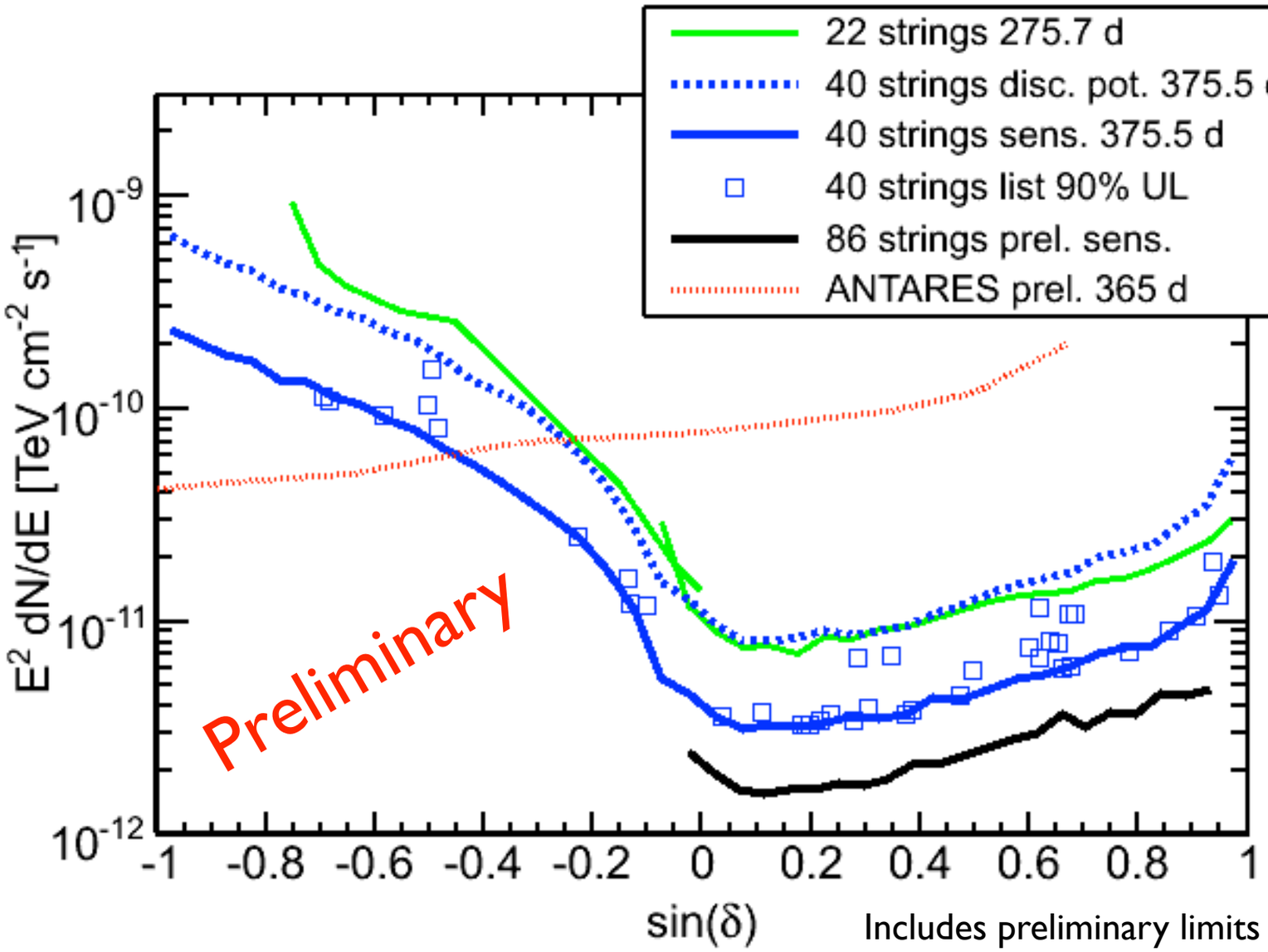
Northern sky:
data dominated by atmospheric neutrinos
energy range: 10s – 100s TeV



Southern sky:
data dominated by atmospheric muons
energy range: > PeV, increasing with zenith angle

exposure: 375.5 days
14121 up-going events
22779 down-going events

Neutrino Point Source Flux Limits



IC-40 discovery potential (5σ)

IC-22 sensitivity (90% c.l.)

IC-40 sensitivity (90% c.l.)

IC-86 prel. sensitivity

Includes preliminary limits on 39 pre-selected point sources, smallest p-value 62% (post-trial)

- Further point source analyses
  - Flare searches
  - Target-of-Opportunity
  - Optical follow-up
  - Multi-wavelength
  - Source stacking → see poster by J. Dreyer
  - Corr. w/ UHECR directions → see talk by R. Lauer

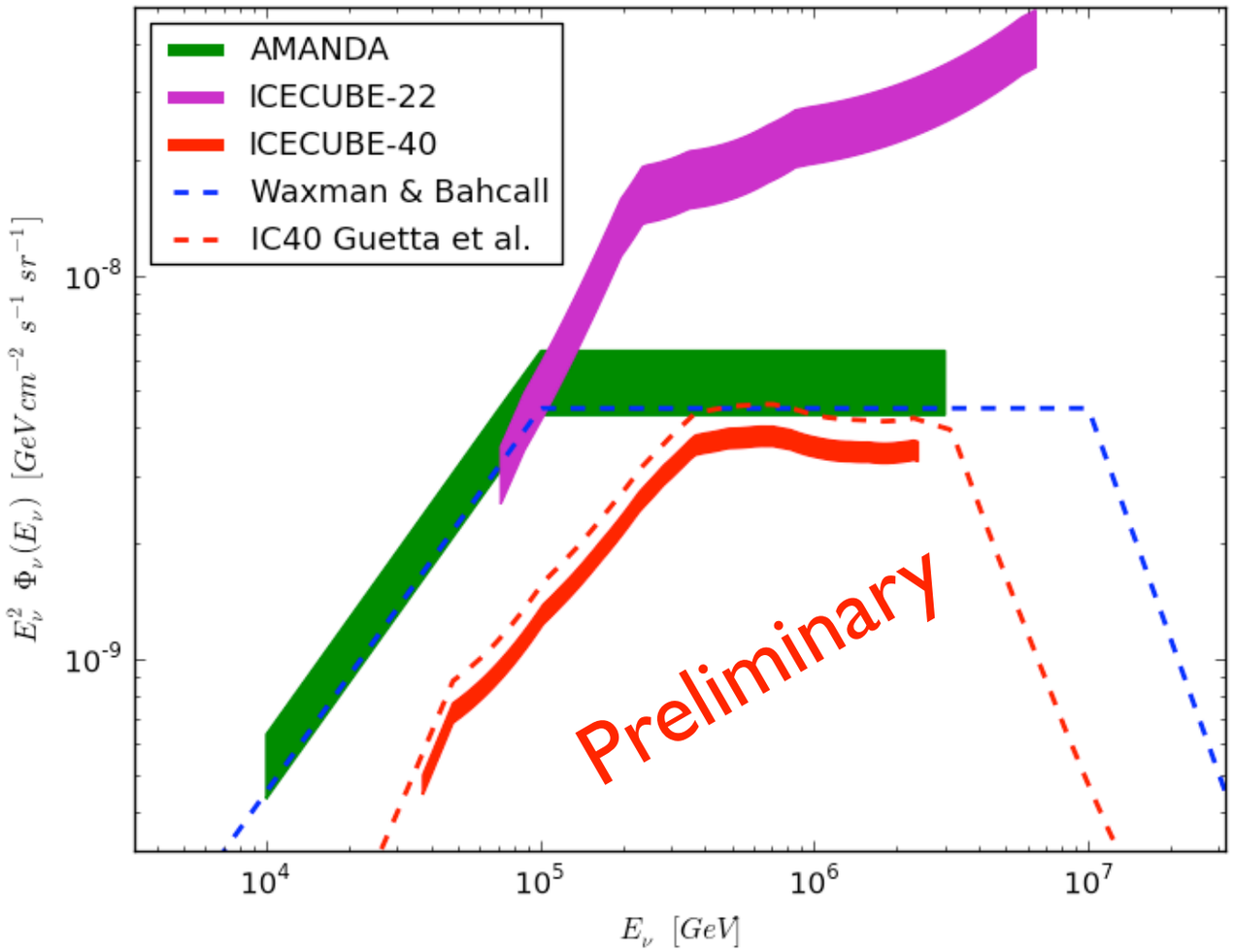
Triggered GRB Searches

- Based on 117 satellite detected gamma-ray bursts in Northern hemisphere

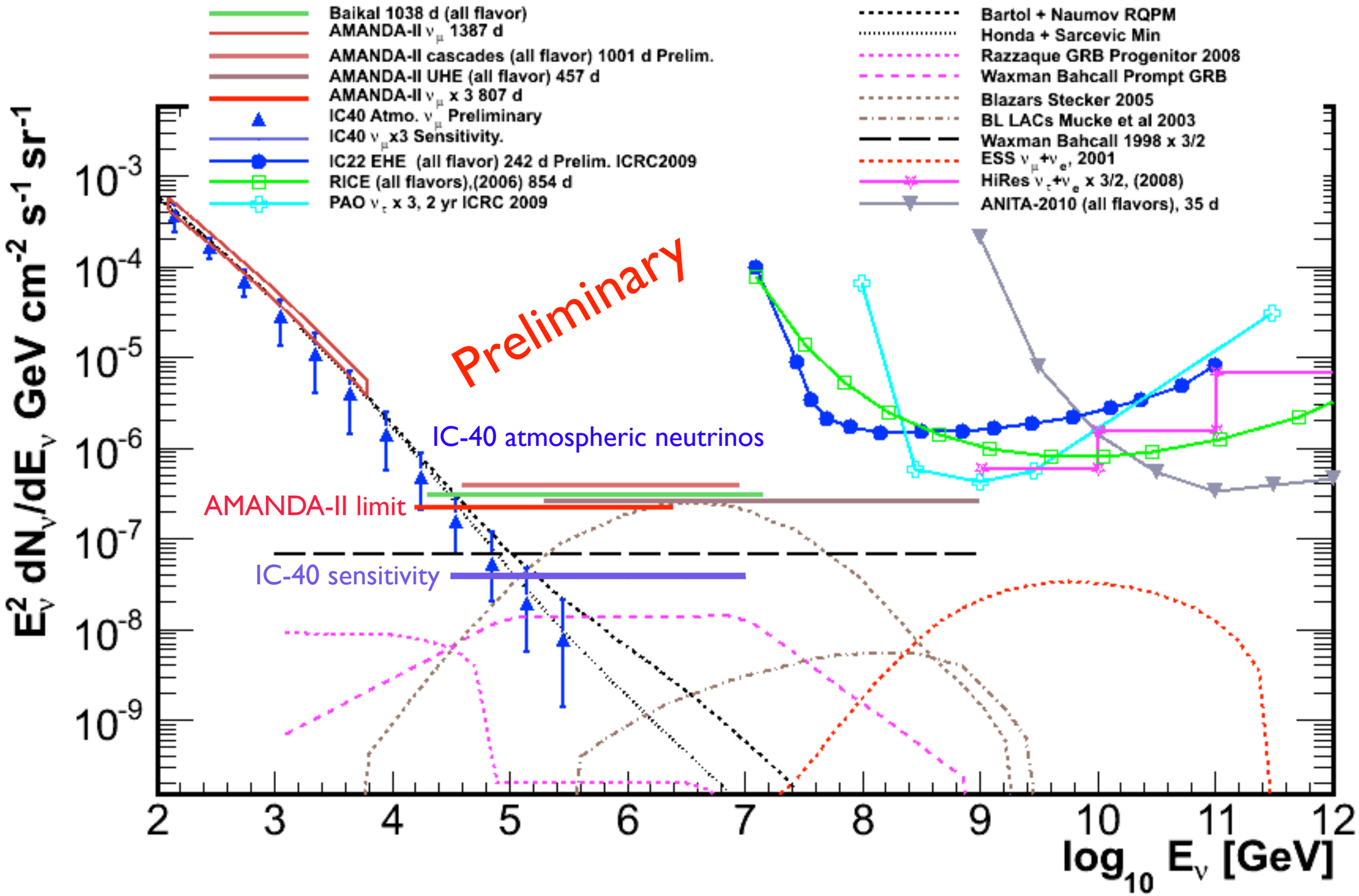
- Search for coincident neutrino events (time and direction) with unbinned likelihood method

- Burst parameters modeled individually

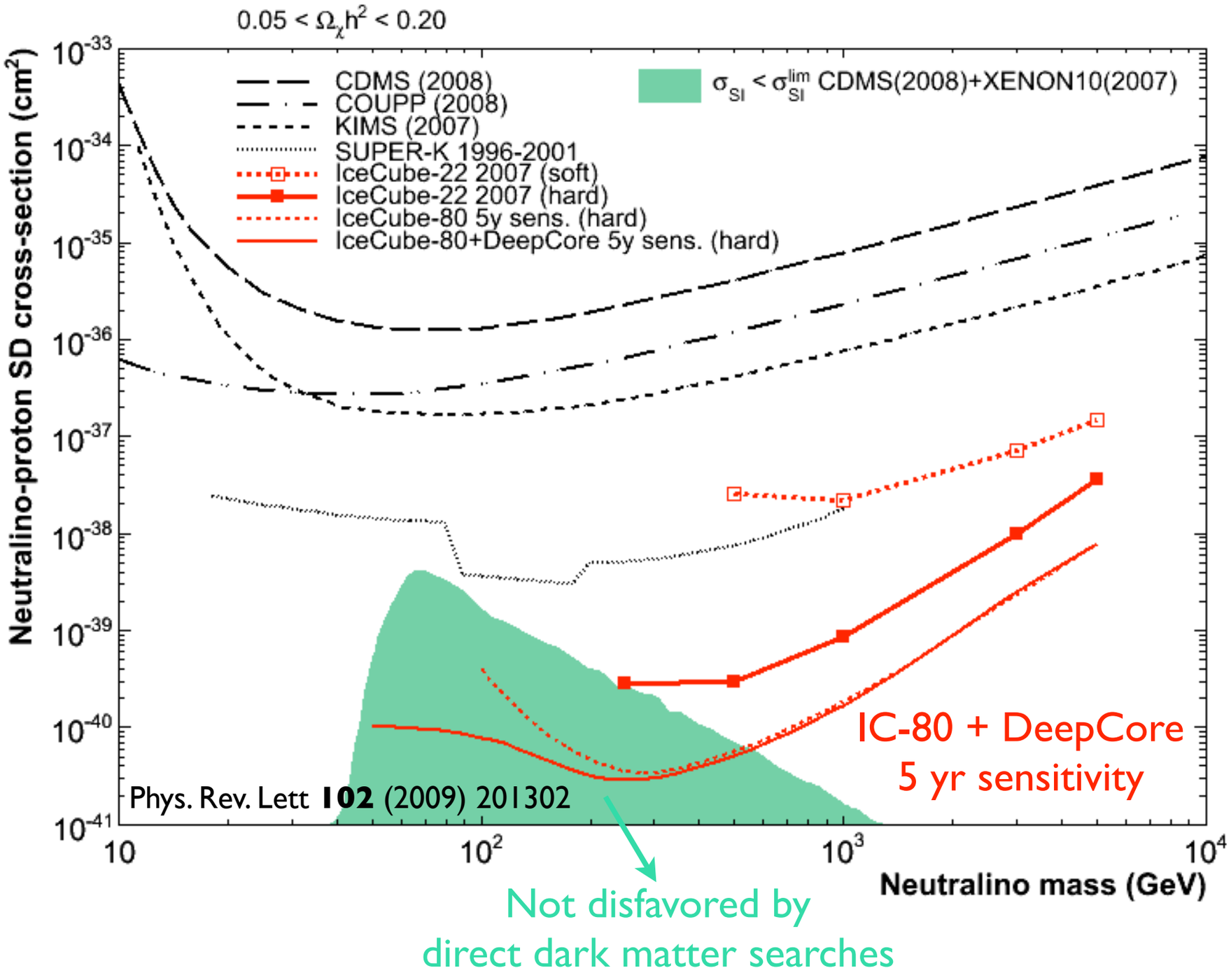
- IceCube limit approaches "standard" Waxman-Bahcall neutrino emission model



Diffuse Neutrino Fluxes



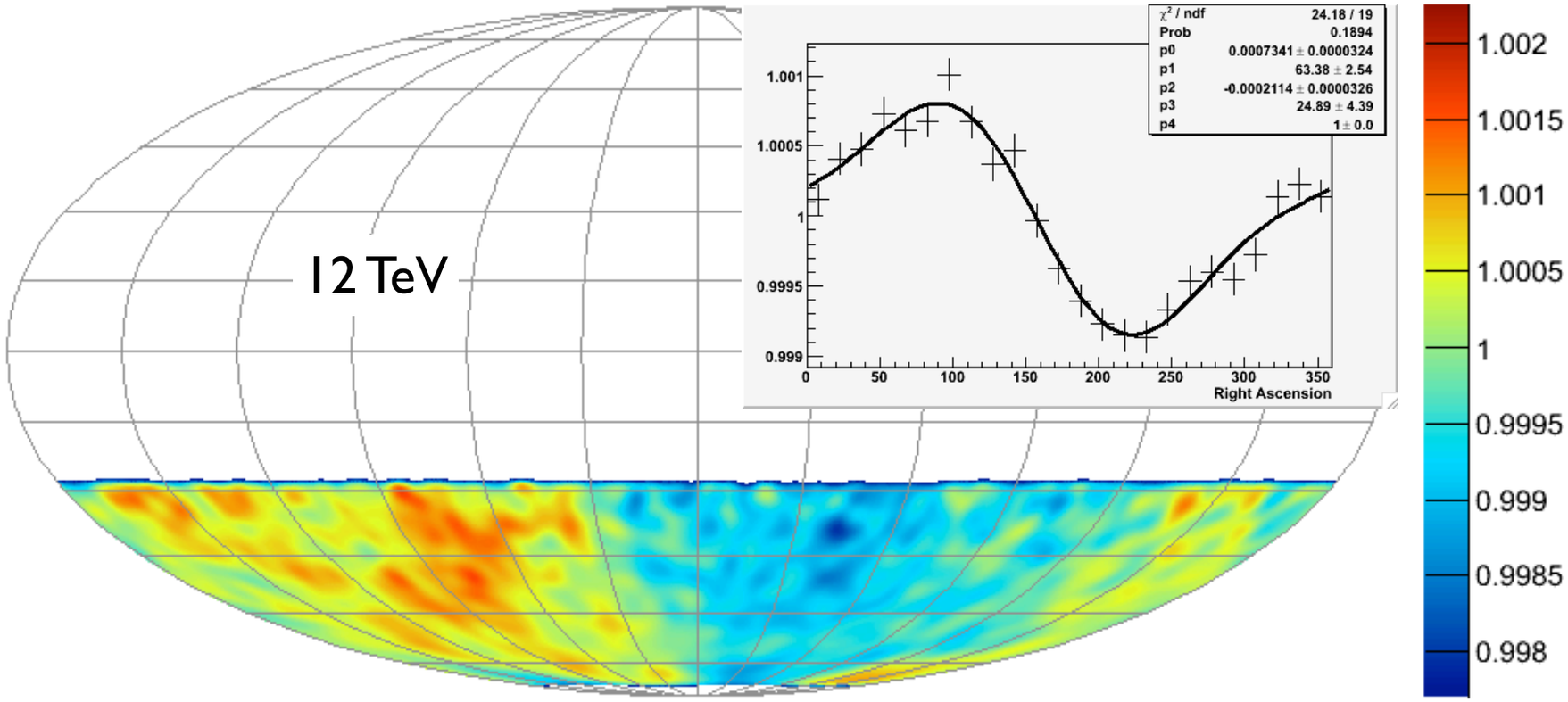
Indirect Dark-Matter Searches



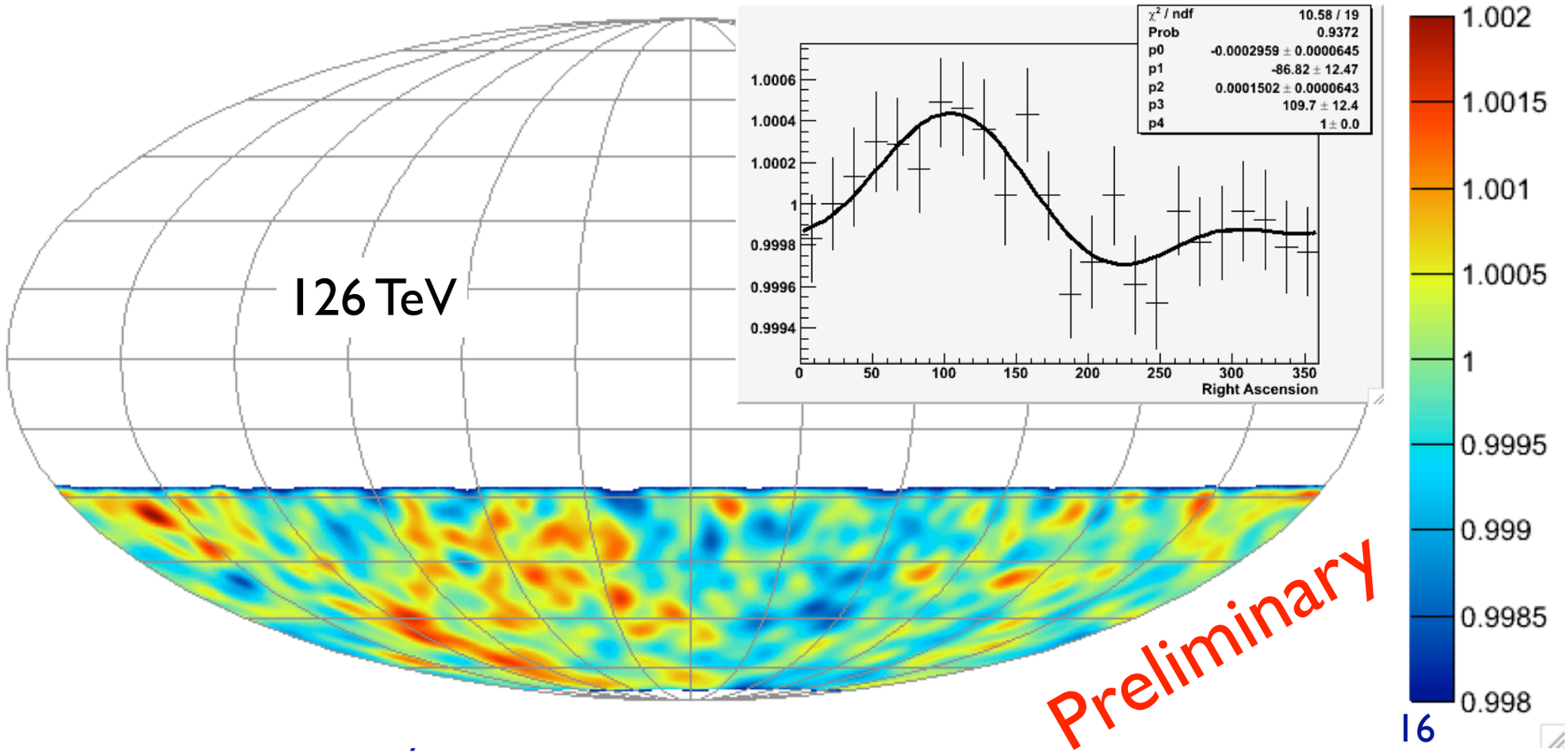
- Neutralino pair annihilation (into neutrinos) in the Sun

Large Scale Anisotropy of Cosmic Rays

- Data: IC-22, 4.3×10^9 atm. muons
- Median angular resolution: 3 deg
- Median energy per cosmic ray particle: ~20 TeV

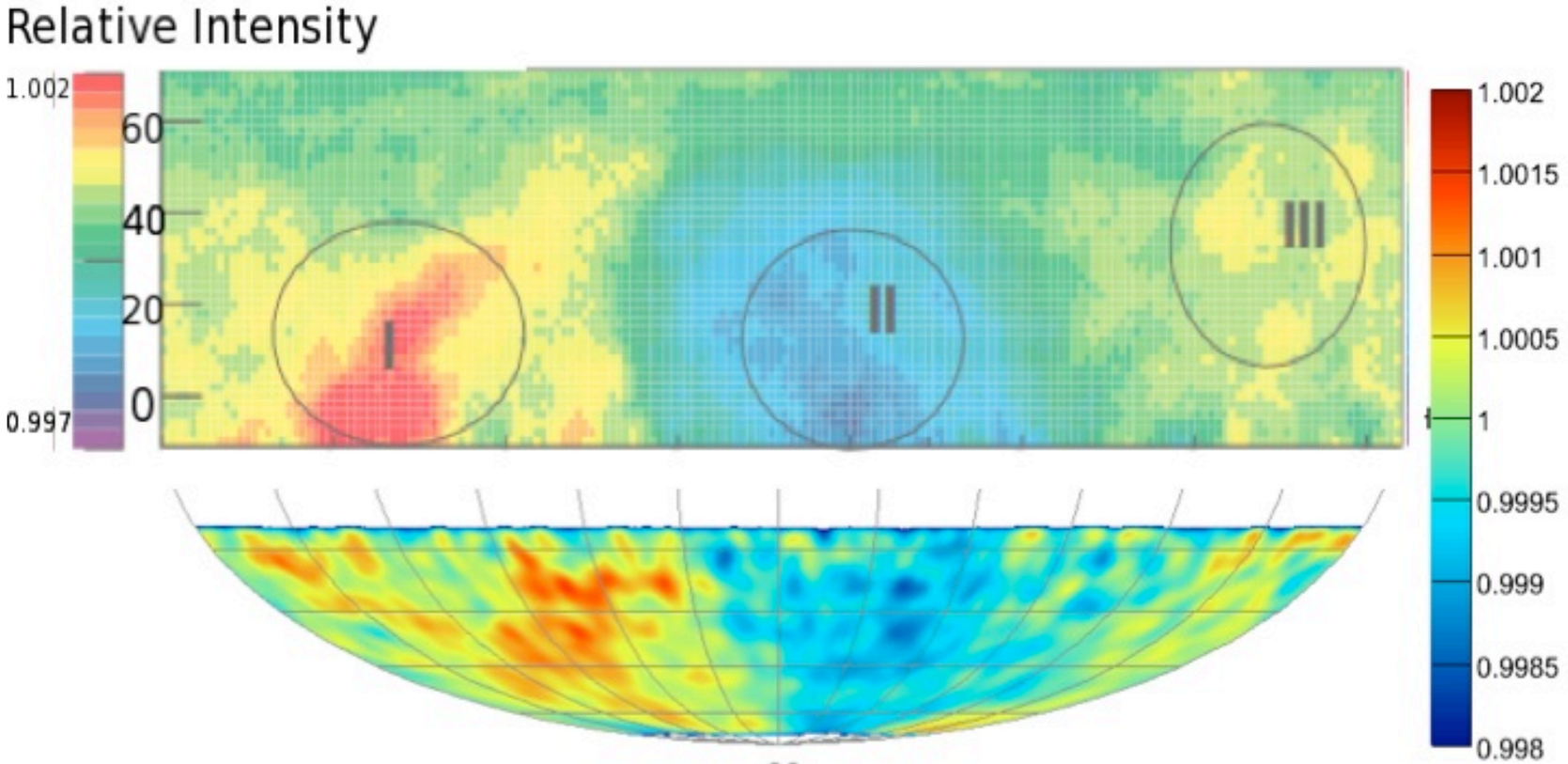


- Observe large scale anisotropy
- Amplitude decreases with increasing CR energy

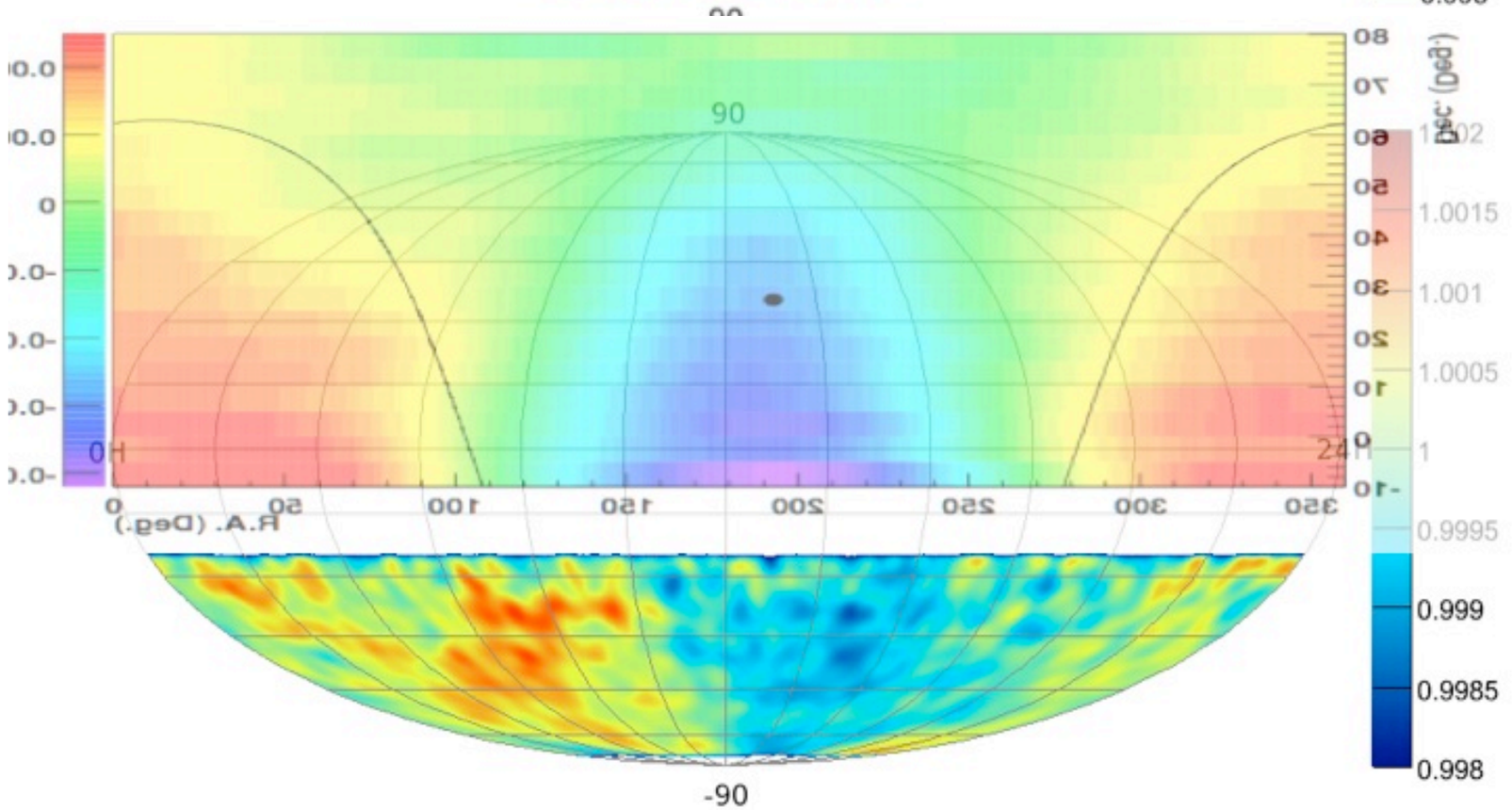


Comparison to Northern Hemisphere

Tibet Array & IceCube

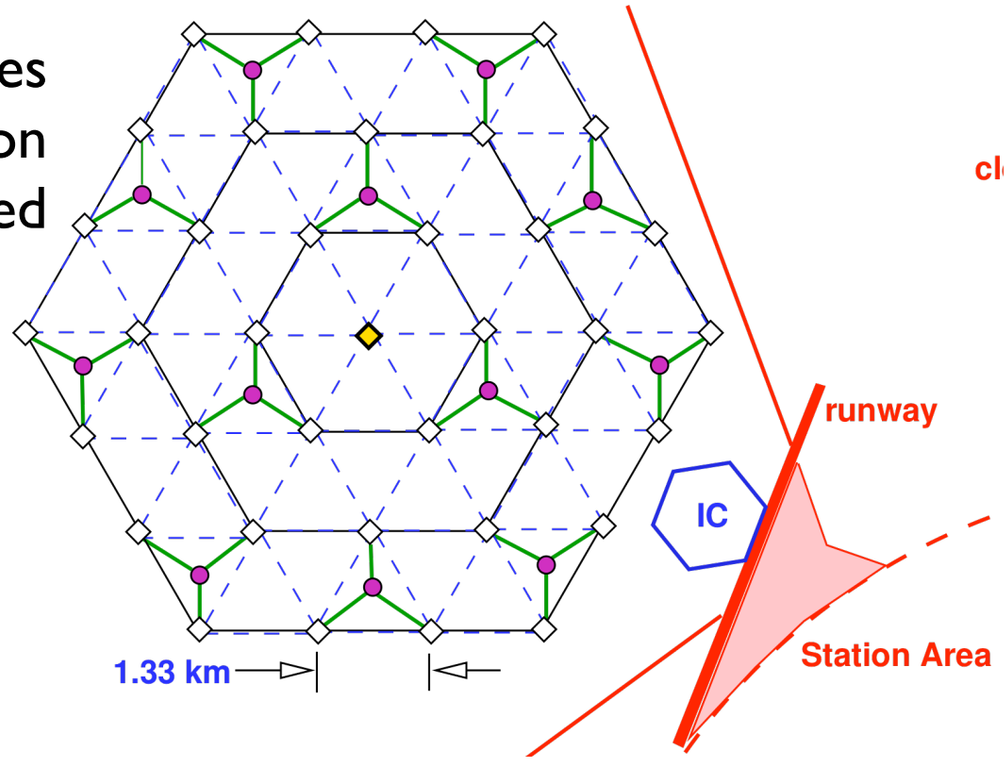


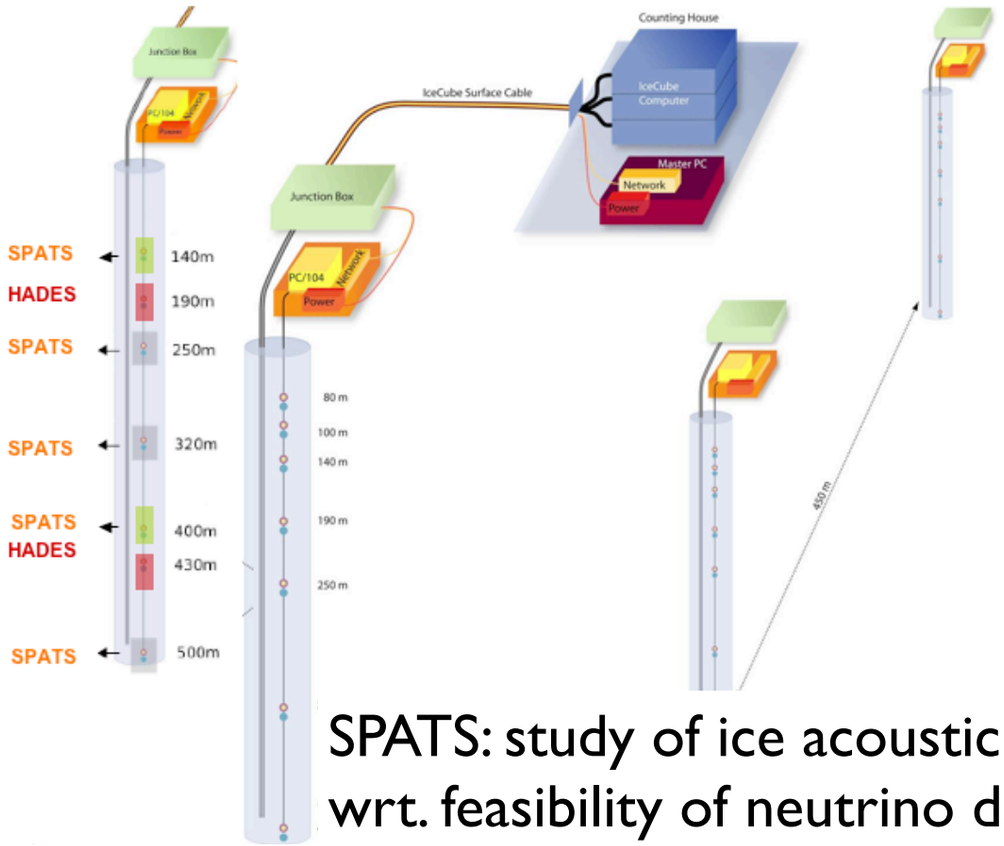
Milagro & IceCube



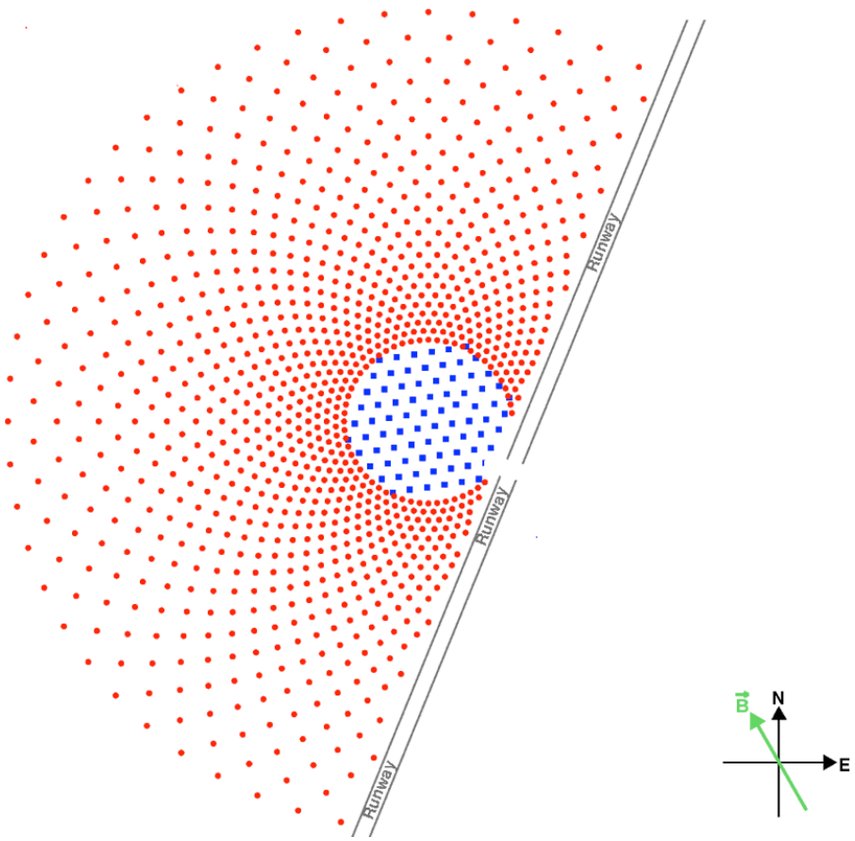
R&D Projects: Radio and Acoustic

NARC: study of ice radio properties
wrt. feasibility of neutrino detection
→ ARA prototype deployment recently funded





SPATS: study of ice acoustic properties
wrt. feasibility of neutrino detection



RASTA: radio air shower detector
to augment IceTop and IceCube
(CR composition,
UHE photon searches,
CR veto for UHE neutrino searches)

Summary and Outlook

- IceCube nearly complete!
  (79 / 86 strings deployed and operating)

- IceCube is detecting neutrinos: ~20000 neutrinos already observed
  in two seasons of partially built detector
  (consistent with expected flux of atmospheric neutrinos)

- Beginning to explore interesting neutrino flux regions

- Cosmic ray anisotropies possibly hinting to local CR sources

- More to come...